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THE SYSTEMATIC ANATOMY OF SOUTH INDIAN *CYPERACEÆ* : *SCIRPUS* L. *S. LAT.*

by E. GOVINDARAJALU

SUMMARY: Thirteen species of *Scirpus s. lato* have been investigated organwise. All of them show certain number of common characters in addition to features which are characteristic of each species. All these taxa may be segregated into two primary groups based upon 2- or 1-layered condition of bundle sheaths in the culms. Further distinction among these two groups of species may be effected in the light of presence or absence of fibrous bundles in the partition of air-cavities, transectional outlines of the culms, cell types in the air-cavities, sclerenchyma types and the number of silica-bodies in the epidermal cells which are all derived from the anatomical structure of the culms. Key is given by making use of the said anatomical characters.

INTRODUCTION

The anatomical information that is now available on the genus *Scirpus* pertains to about 63 species in all out of a total of *c.* 120 species. As it is this particular situation seems to be neither adequate for the proper understanding and elucidation of certain taxonomic problems involved in this taxon nor the available accounts lend themselves for unequivocal comparison for want of uniform treatment by the early workers since the taxa had all been studied from altogether different standpoints except 15 species recently dealt with by METCALFE (1971). Out of 13 South Indian species, SABNIS (1921) had studied the anatomy of sheath and culm of *S. maritimus;* MULLAN (1945) the complete vegetative anatomy of *S. grossus;* D'ALMEIDA & RAMASWAMY (1948) the anatomy of vegetative organs and the inflorescence axis of *S. maritimus, S. grossus* and *S. litoralis* from the ecological standpoint and MEHRA & SHARMA (1965) from the standpoint of distribution of silica-bodies. Furthermore as pointed out by the present author (GOVINDARAJALU, 1974) that in all the early works sufficient emphasis has not been laid on those anatomical characters that are now found to be useful and important in taxonomic considerations. It may be mentioned that METCALFE (1971) has contributed anatomical information on 2 South Indian species (*S. fluitans, S. maritimus*) which seems to be the only dependable and useful account from the above

mentioned points of view. However a few discrepancies with respect to these two species have come to light between his observations (METCALFE, 1971) and those of mine thereby warranting the necessity of including them in this work. As it is no information of any kind is available for *S. articulatus*, *S. brachyceras*, *S. jacobi* and *S. subcapitatus* and as far as the rest of the South Indian species are concerned it seems to be either scanty or incoherent and incomplete. For other kinds of miscellaneous information such as embryology, developmental anatomy, etc., see METCALFE (1971). Out of 13 species covered in this work 2 species (*S. validus* and *S. roylei*) not represented in South Indian flora have been included.

MATERIAL AND METHODS

All the materials used in the present investigation are from the collections available in the Herbarium of the Presidency College, Madras and cited as PCM. In addition to this, fresh materials wherever available for certain species were fixed in the field. The full citation of specimens is given at the end of the description of each species. For the sake of avoiding repetition in the citation of specimens, the first two letters of the collector's name are given (e.g. *Go.* = *Govindarajalu*).

Methods which have been followed earlier (GOVINDARAJALU, 1966; 1968 a, b; 1969) are adopted here also. The characterization of the type of vascular bundles and metaphloem is after CHEADLE & UHL (1948 a, b). The common characters that have been already reported for the genus by METCALFE (1971) are indicated here as (MET.). Most of the descriptive terms used in this work are those that have been proposed by METCALFE & GREGORY (1964).

CHARACTERS COMMON TO THE SPECIES EXAMINED

1. Stomata paracytic in sheaths, culms and leaves; subsidiary cells parallel-sided in all; low dome-shaped in culms of *S. brachyceras*.
2. Intercostal cells in sheaths and culms with straight end walls.
3. Interstomatal cells in sheaths (except *S. subcapitatus*) and culms with concave end walls.
4. Bulliform cells absent in sheaths.
5. Air-cavities in sheaths and leaves containing stellate parenchyma (Pl. 4, *3*, *10*, *14*) except *S. jacobi* (Pl. 4, *9*) and *S. litoralis* (Pl. 4, *8*) in which lobed cells present.
6. Bundle sheaths in sheaths double, complete; O.S. parenchymatous, I.S. fibrous except *S. maritimus*, *S. roylei;* bundle sheaths in culms 2-layered, O.S. parenchymatous, I.S. fibrous (MET.) but single-layered in *S. brachyceras*, *S. grossus*, *S. validus*, *S. subcapitatus* and *S. litoralis* (Pl. 2, *7*).
7. Conical silica-bodies in leaves and culms surrounded by satellites but the latter wanting in the culms of *S. lateriflorus* and *S. maritimus* (MET.).

8. Adaxial epidermal cells of the leaf larger than those of the abaxial (MET.) (Pl. 4, *13*).
9. Circumvascular sclerenchyma present as a cap at the xylem pole in sheaths of all the taxa (Pl. 4, *3*) but absent in *S. fluitans* and *S. jacobi* (Pl. 4, *9*, *12*).
10. Secretory cells in sheaths and leaves varying from less common to abundant (MET.) (Pl. 4, *1*, *4*, *9*, *12*, *13*, *14*).
11. Sclerenchyma strands in sheaths trapezoid or trapezoid to rounded in the majority of the taxa (Pl. 4, *8*, *9*, *10*, *14*); rounded in *S. maritimus* and *S. roylei*.
12. Metaphloem in all the organs belongs to " regular type " while that of sheaths of *S. subcapitatus* to " intermediate type ".
13. Cuticle usually thick in sheaths (Pl. 4, *14*), but thin in culms of *S. fluitans* (Pl. 3, *2*) and leaves (Pl. 4, *13*).

DESCRIPTIONS OF INDIVIDUAL SPECIES

Scirpus articulatus L.

SHEATH. *Abaxial surface:* Intercostal cells moderately elongated, broad; cell walls thick, pitted and smooth. Stomata (L. 32-36 μ; W. 20-24 μ); subsidiary cells parallel-sided; interstomatal cells short. Silica-cells elongated, narrow, thick-walled, smooth, occurring in a single discontinuous row, each cell possessing 2-4(-5) small cone-shaped silica-bodies with satellites.

Transverse section: Cuticle very thick on either surface. Epidermal cells isodiametric and similar in both surfaces. Hypodermis: abaxial 2-layered, adaxial 1-layered, both containing colourless cells. Air-cavities large, as many as and alternating with vb's, each cavity occupied with stellate parenchyma cells. Sclerenchyma (Ht. 28-60 μ; W. 32-52 μ) trapezoid strands. Vascular bundles many, large (type III A) and small (type I), not regularly alternating with each other. Metaxylem vessel members (D. 20-24 μ). Metaphloem: " regular type ". Bundle sheaths: O.S. parenchymatous, I.S. fibrous, both complete. Circumvascular sclerenchyme rectangular forming a cap at the xylem pole. Secretory cells less common. Starch grains common.

CULM. *Epidermis, surface view:* Cells elongated, narrow, thick-walled, smooth with straight end walls. Stomata (L. 40-44 μ; W. 20 μ), narrowly oblong; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells short, narrow, thick-walled, occurring in a single discontinuous row, each cell containing 2(-3) small conical silica-bodies with satellites.

Transverse section (Pl. 1, *2*) : Outline circular. Cuticle moderately thick, smooth. Epidermal cells thick-walled. Air-cavities many, variable, irregular in distribution in the centre, filled with lobed parenchyma cells; however air-cavities in the periphery forming a circle and almost regularly alternating with vb's. Vascular bundles many, large (type III B) and small (type I) arranged more or less in 3-4 circles; large vb's containing protoxylem lacunæ; metaxylem vessel members (D. 48-60 μ); metaphloem of "regular type". Bundle sheaths: O.S. parenchymatous, I.S. fibrous, both complete. Sclerenchyma (Ht. & W. 32-48 μ) trapezoid and polyhedral hypodermal strands. Circumvascular sclerenchyma crescentiform forming a cap at the xylem pole in all the large vb's and appearing rectangular in all the small vb's. Secretory cells not seen. Starch grains abundant in parenchyma cells of the ground tissue.

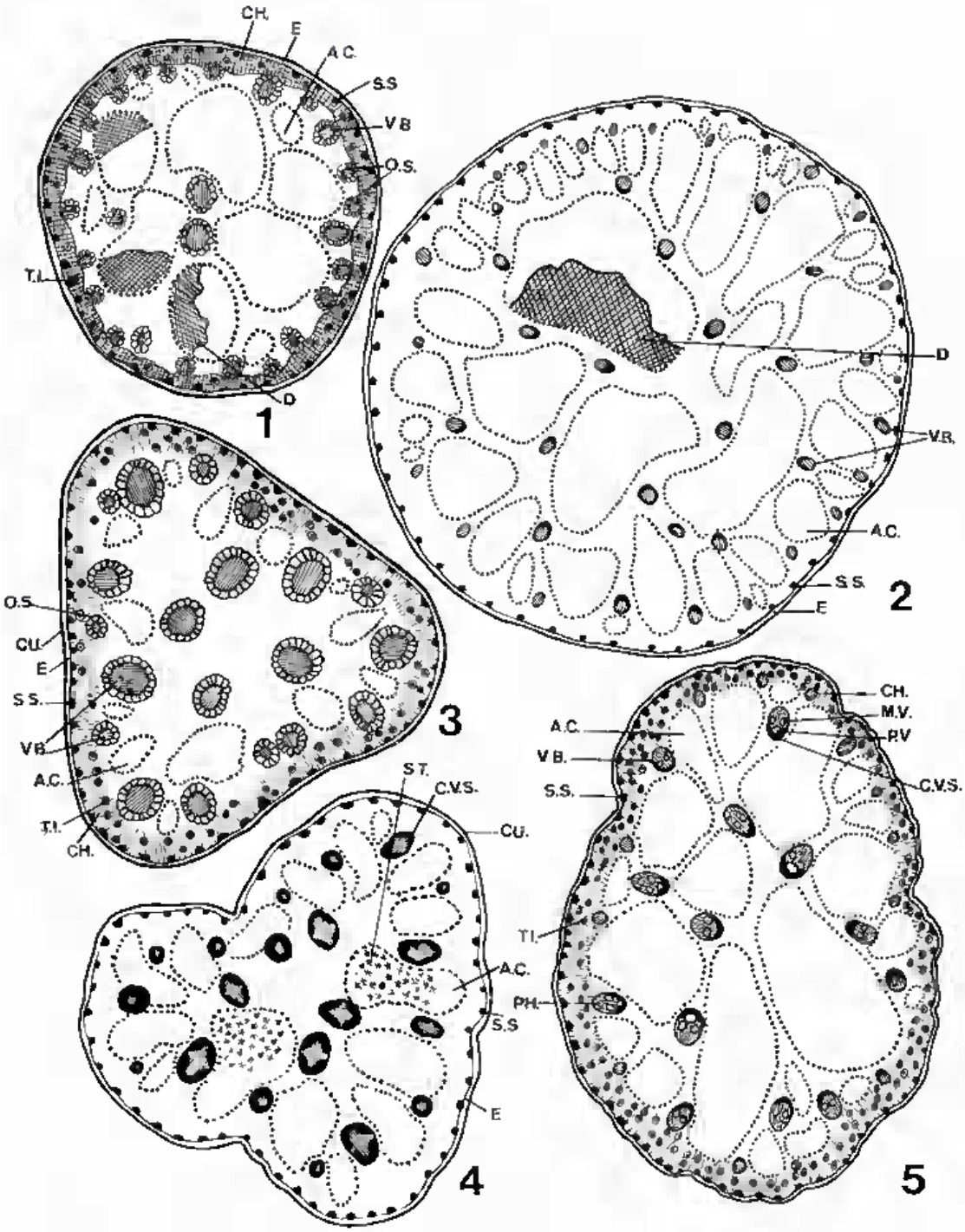
ROOT. *Transverse section:* Diameter of the root examined *c.* 0.7 mm. Exodermal cells variable, thick-walled. Hypodermis consisting of 2 layers of sclerenchyma. Cortex: outer lacunose, consisting of concentrically arranged air-cavities separated by radiating rows of parenchyma; inner cortex of 2-3 layers of compactly arranged parenchyma cells being in radial alignment with endodermal cells. Endodermis: cells with U-shaped thickening. Metaxylem element central, solitary (D. 44-48 μ); protoxylem units 10 in number; metaphloem not easily recognizable. Central ground tissue parenchymatous.

MATERIAL EXAMINED: Mayuram, Thanjavur Dt., *Govindarajalu 5781;* Thiruvottiyur, Madras Dt., *Go. 5761;* Vedanthangal, Chinglepet Dt., *Go. 5737;* Ennore, Madras Dt., *Go. 5621;* Aminjikarai, Madras Dt., *Go. 5654;* Coleroon river bed, Thanjavur Dt., *Go. 6847;* Trichirapalli, Trichirapalli Dt., *Go. 5814;* Kumbakonam, Thanjavur Dt., *Go. 7133;* Sriperumpudur, Chinglepet Dt., *Go. 5683.*

Scirpus brachyceras Hochst. ex A. Rich. (*S. corymbosus* Heyne ex Roth *non* L.) (only culm examined)

CULM. *Epidermis, surface view:* Epidermal cells short, more or less elongated, smooth, thick-walled. Stomata abundant (L. 45.0-48.6 μ; W. 32.4-36.0 μ); subsidiary cells low dome-shaped. Silica-cells in 1 (-2) continuous rows, each cell possessing 2-3 (-4) conical silica-bodies with satellites sometimes containing silica particles also.

Transverse section (Pl. 2, *5*): Outline obtusely tetragonous, minutely corrugated due to the presence of unequal heights in the epidermal cells. Epidermal cells thick-walled, variable. Stomata many, sunken in the furrows; guard cell with thickened walls; substomatal chamber narrow. Assimilatory tissue of more or less of rounded short cells occurring in 6-8 hypodermal layers. Air-cavities very many, variable, reticulate and reaching the centre; air-cavities with reference to type of diaphragm cells being of two kinds; one kind containing stellate parenchyma cells not traversed by transverse veins while the other one with radially elongated lobed thick-walled parenchyma permeated by transverse veins. Vascular



Pl. 1. — Transverse section of culm, ground plan : **1, Scirpus juncoides** Roxb. × 25; **2, S. articulatus** L. × 10; **3, S. lateriflorus** Gmel. × 30; **4, S. roylei** (Nees) Parker × 40; **5, S. jacobi** Fischer × 30.

bundles very many, of 3 different sizes (large, medium and small), all belonging to type III A; medium and small vb's alternating with each other and thus forming a circle in the periphery; large vb's containing protoxylem lacunæ; metaxylem vessel members (D. 18.0-21.6 μ); metaphloem of " regular type ". Bundle sheaths: single-layered, complete, fibrous. Sclerenchyma: hypodermal, pulviniform, many (Ht. 23.4-27.0 μ; W. 27.0-28.8 μ); small fibre bundles, also present in the chlorenchyma, each one of them occurring in units of (2-) 3-6 cells and alternating with hypodermal strands; fibre bundles (Ht. 10.8-12.6 μ; W. 5.4-12.6 μ). Circumvascular sclerenchyma crescentiform forming a cap at xylem and phloem poles in all the large vb's; medium vb's with triangular (pulviniform) cap at the xylem pole; small vb's usually with pulviniform (triangular) cap at the xylem pole. Secretory cells not seen.

MATERIAL EXAMINED: *T.T.D. 8455* (*s. loco*).

Scirpus fluitans L.

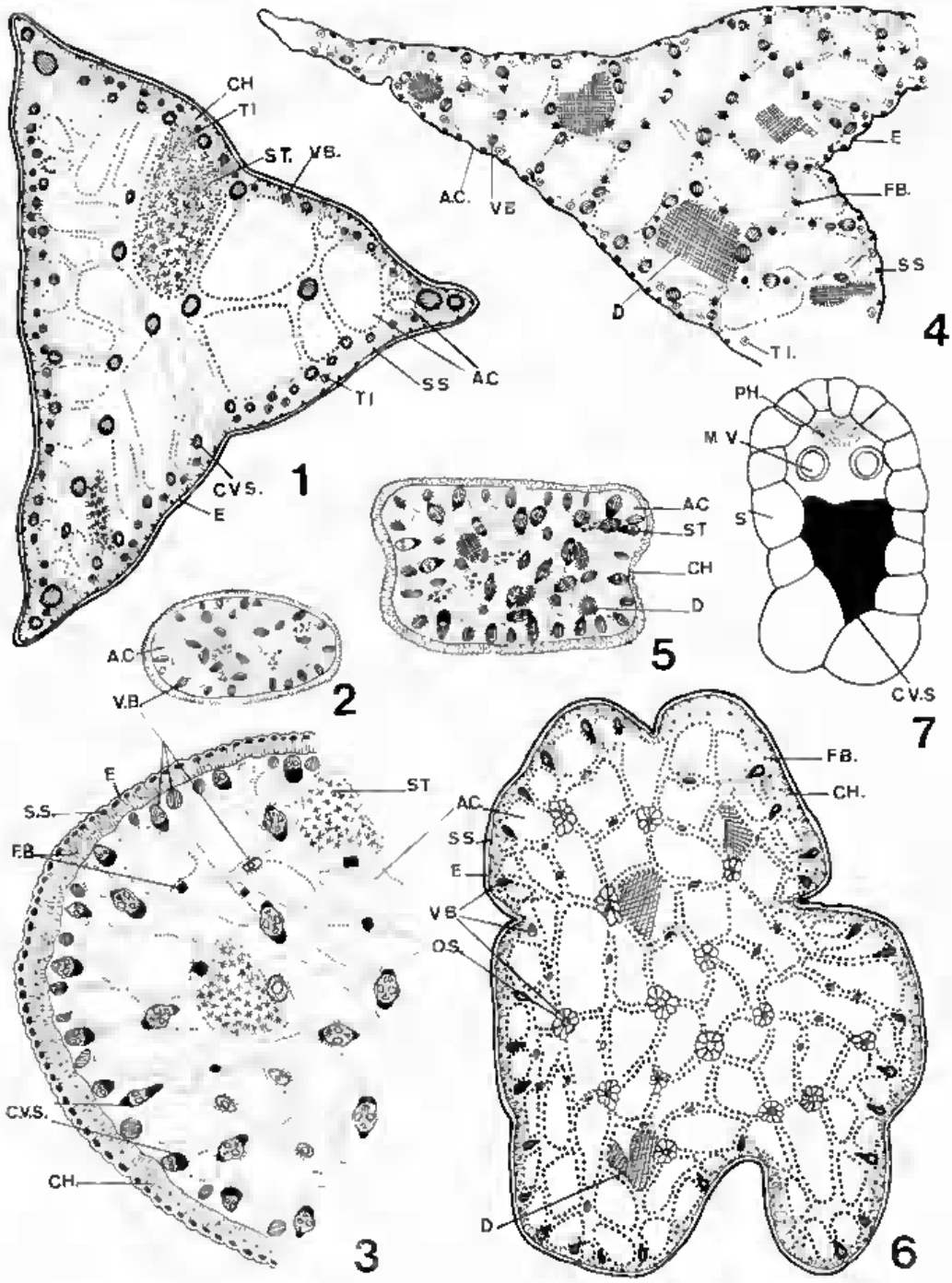
SHEATH. *Abaxial surface:* Intercostal cells axially elongated, broad, moderately thick-walled, pitted, smooth with straight end walls. Stomata (L. 32-36 μ; W. 24 μ), narrowly elliptical; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells short, broad, thin-walled, smooth, present in a single continuous row, each cell containing 1-2 conical silica-bodies with satellites.

Transverse section (Pl. 4, *12*): Outline crescent-shaped. Epidermal cells thick-walled, similar on both surfaces. Abaxial hypodermis composed of single layer of parenchyma. Air-cavities *c.* 4, variable in size, irregular in outline and regularly arranged; air-cavities containing stellate parenchyma. Sclerenchyma strands (Ht. & W. 12-16 μ) trapezoid. Vascular bundles 5, large (type III A) and small (type I); median vb larger, submarginal and marginal vb's progressively becoming smaller. Bundle sheaths: O.S. of inflated parenchyma cells, I.S. fibrous both complete. Circumvascular sclerenchyma not developed. Secretory cells common.

LEAF. *Abaxial surface:* Intercostal cells axially elongated; cell walls moderately broad, thin-walled, smooth; end walls straight. Stomata (L. 32-36 μ; W. 24 μ) oval-shaped; subsidiary cells parallel-sided; interstomatal cells axially elongated with straight end walls. Long cell sometimes containing silica particles. Silica-cells elongated, narrow, thin-walled, smooth, occurring in a single discontinuous row; silica-bodies small, conical, 4-6 in each cell; satellites absent.

Adaxial surface: cells elongated, hexagonal, thin-walled, smooth, broad; end walls straight. Silica-cells, see abaxial surface.

Lamina, transverse section (Pl. 4, *13*): Outline adaxially concave and slightly abaxially convex throughout; keel absent; margins truncate. Assimilatory tissue composed of 2-3 layers of chlorenchyma on the adaxial



Pl. 2. — Transverse section of culm, ground plan: **1, Scirpus mucronatus** L. × 10; **2, S. validus** Vahl, diagrammatic; **3,** *id.*, in part × 25; **4, S. grossus** L.f., in part × 10; **5, S. brachyceras** Hochst. ex A. Rich., diagrammatic; **6, S. litoralis** Schrad. × 10; **7,** *id.*, vascular bundle × 160.

surface. Air-cavities 3, large, slightly variable, irregular in outline, containing stellate parenchyma and regularly alternating with vb's. Bulliform cells not differentiated. Vascular bundles 4 more or less of same size and disposed in a single row; metaxylem vessel members (D. 8 μ); metaphloem of " regular type ". Bundle sheaths: O.S. of inflated parenchymatous cells and I.S. fibrous, both complete. Sclerenchyma strands (abaxial; Ht. & W. 16 μ) trapezoid; adaxial strands (Ht. & W. 12 μ) rectangular, both hypodermal; abaxial strands 11 and adaxial strands 4 in number. Secretory cells common.

CULM. *Epidermis, surface view:* Cells elongated, broad, thin-walled, smooth. Stomata not observed. Silica-cells occurring in 1 (-2) continuous rows, each cell containing 3 conical bodies surrounded by satellites.

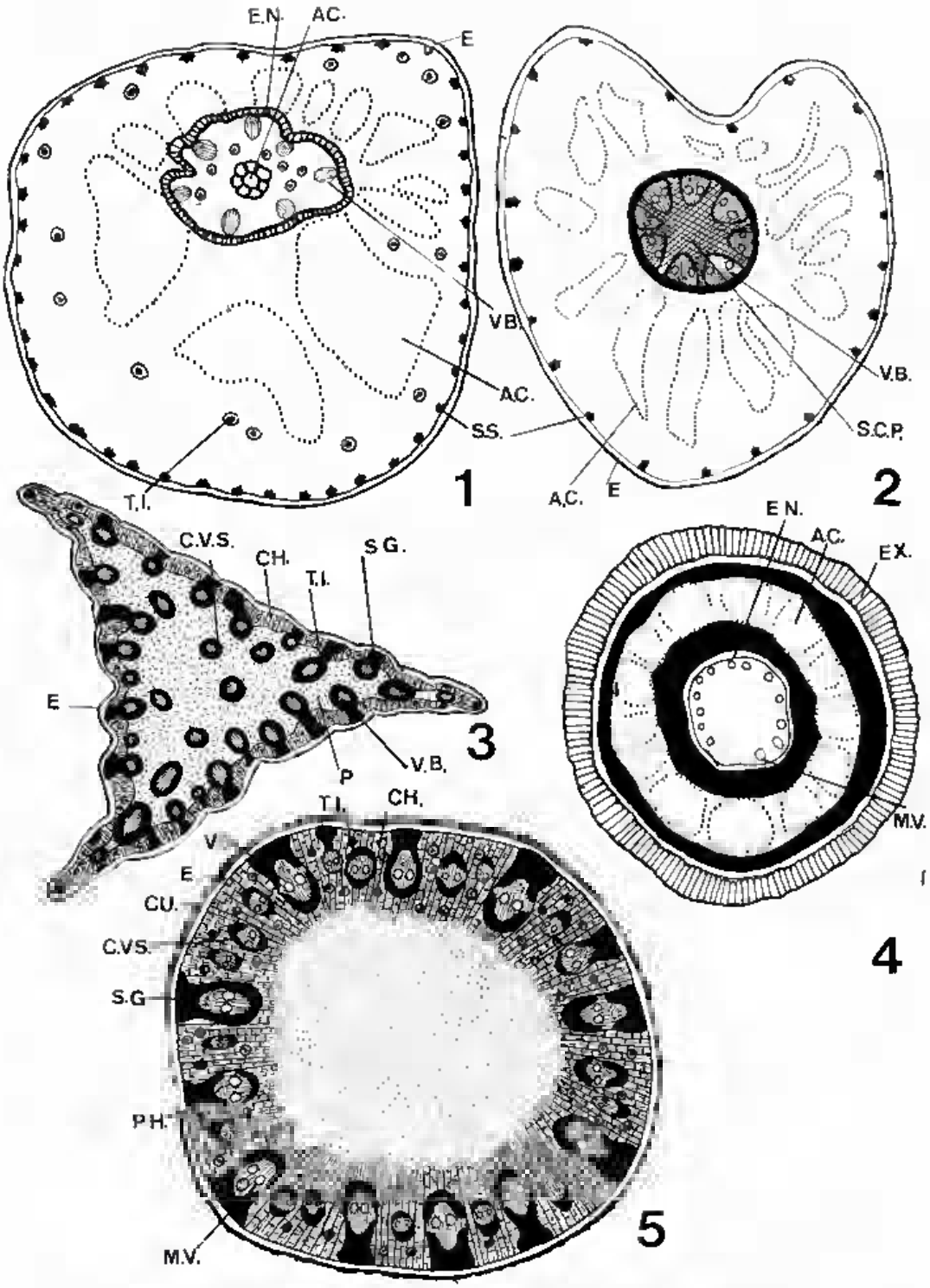
Transverse section (Pl. 3, *2*): Outline scutiform. Cuticle thin. Epidermal cells thin-walled. Assimilatory tissue: 2-3 layers of rounded chlorenchyma cells. Air-cavities *c.* 15, radially elongating, variable in size and shape, forming a circle in the periphery. Vascular bundles 7-8 arranged in a circle in the centre of the culm (Pl. 3, *2*) and belonging to type III A or B; metaxylem vessel members (D. 12-16 μ). Bundle sheaths: not recognizable because of the sclerenchyma enveloping all around the vb's. Sclerenchyma: hypodermal strands *c.* 21 (Ht. 20-24 μ; W. 36-44 μ) pulvinifomr with angular sides. Secretory cells common. Central ground tissue sclerenchymatous.

In METCALFE'S material, 5 air-cavities, 5 vb's, 16 sclerenchyma strands and oval outline for the culms have been reported (METCALFE, 1971).

RHIZOME. *Transverse section* (Pl. 3, *1*): Diameter of rhizome examined *c.* 1 mm. Outline somewhat oval-shaped. Cortex consisting of radiately arranged air-cavities, 11 in number, variable in size and shape and arranged in a peripheral circle. Endodermis: conspicuous, and its cells with prominent U-shaped thickenings. Stele consisting of 7-8 collateral vb's forming a ring. Sclerenchyma strands: hypodermal, *c.* 40 in number, trapezoid, small. Secretory cells less common. Solitary schizogenous cavity present in the centre (cf. METCALFE, 1971).

ROOT. *Transverse section:* Diameter of the root examined *c.* 0.2 mm. Epidermal cells thin-walled. Cortex: outer, see *S. articulatus;* inner cortex consisting of 2-3 layers of sclerenchyma arranged radially in alignment with endodermal cells. Endodermis: prominent, cells isodiametric with uniform thickening throughout and circular lumina. Pericycle not easily recognizable. Metaxylem element central, solitary; protoxylem units 4-5 in number; metaxylem vessel members (D. 28 μ); metaphloem not easily distinguishable. Central ground tissue sclerenchymatous.

MATERIAL EXAMINED: Nilgiris, Nilgiris Dt., *Govindarajalu 6126;* Doddabettah, Nilgiris Dt., *Go. 6205;* Naduvattam, Nilgiris Dt., *Go. 6132;* Munnar, Madurai Dt., *Jagannathan 35;* Kodaikanal, Madurai Dt., *Chrispin Devadoss 15;* Pillar Rocks, Kodaikanal, Madurai Dt., *Bourne 1219.*



Pl. 3. — **Scirpus fluitans** L. : **1**, T.S. rhizome, ground plan × 60; **2**, T.S. culm, ground plan × 50. — **S. maritimus** L. : **3**, T.S. culm, ground plan × 36. — **S. subcapitatus** Thw. : **4**, T.S. root, ground plan × 50; **5**, T.S. culm, ground plan × 50.

Scirpus grossus L.f.

LEAF. *Abaxial surface:* Intercostal cells moderately elongated, broad; cell walls thick, sinuous, pitted; end walls straight. Stomata (L. 44-52 μ; W. 32 μ) with thickened walls throughout; subsidiary cells low dome-shaped; interstomatal cells moderately elongated with straight end walls. Silica-cells elongated, narrow, thick-walled, sinuous, occurring in 2 (-3) more or less discontinuous rows; silica-bodies (3-) 5-6, conical, surrounded by satellites.

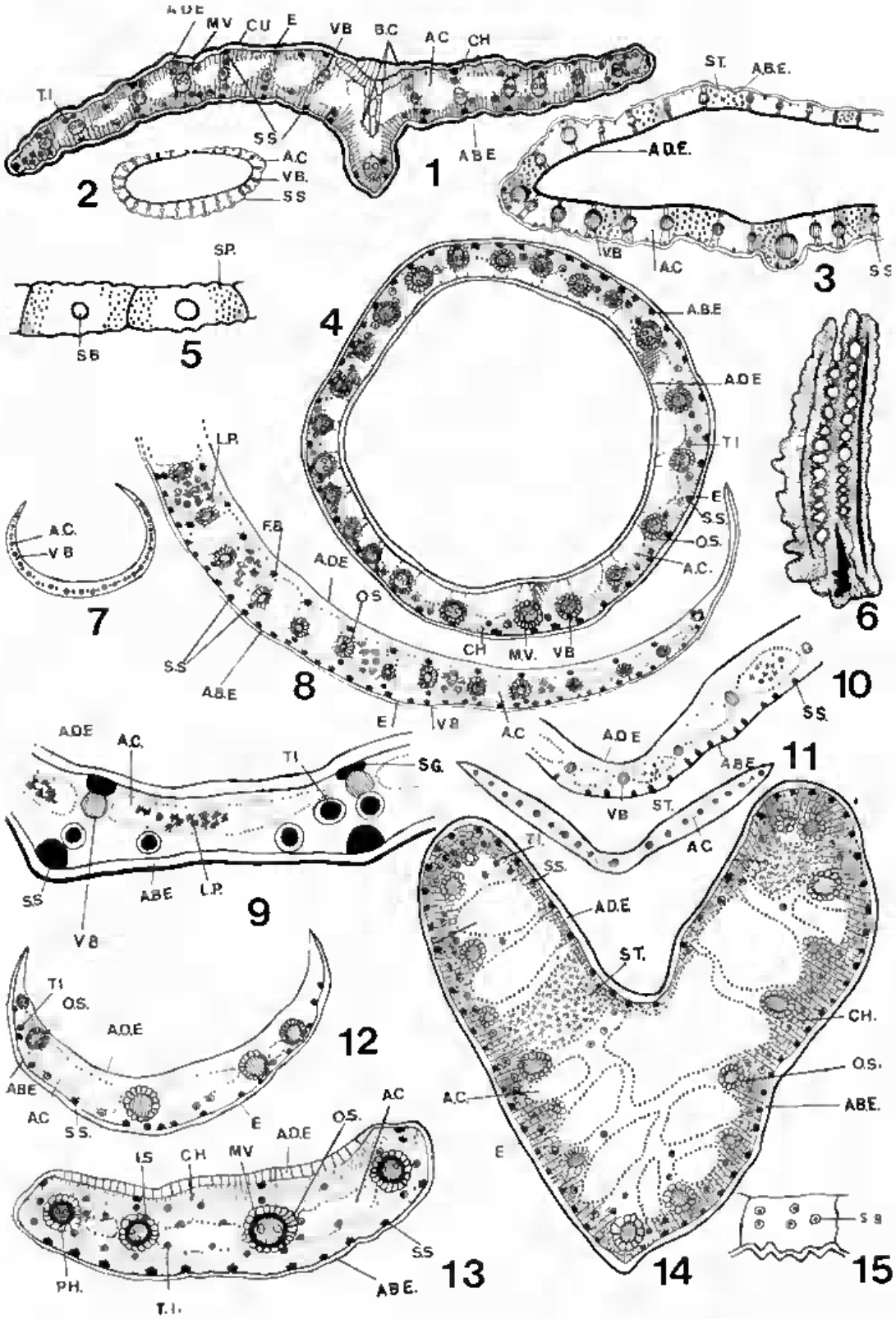
Adaxial surface: see abaxial surface.

Lamina, transverse section: Outline flanged V-shaped, assymmetrical; keel triangular; margins subacute. Hypodermis: single layer of translucent cells beneath adaxial surface. Assimilatory tissue: 2-3 layers of chlorenchyma present on either surface bordering the air-cavities. Air-cavities as many as and regularly alternating with vb's; air-cavities containing two kinds of diaphragm tissue; some of the air-cavities with many long-armed, thin-walled parenchyma and large intercellular spaces and certain others filled with a transverse plate of exceedingly thick-walled elongated cells with peg-like lobes. Bulliform cells 13 present in a regular fan-shaped group. Vascular bundles 45 (24 + 1 + 20) comprising large (type III B) and small vb's (type III A) regularly alternating with each other; metaxylem vessel members (D. 60-64 μ); large vb's containing protoxylem lacunæ; metaphloem of "regular type". Bundle sheaths: O.S. of enlarged parenchyma cells, complete, I.S. fibrous, incomplete. Circumvascular sclerenchyma forming caps both at xylem and phloem poles. Sclerenchyma strands (Ht. 60-100 μ; W. 80-100 μ) usually pulviniform with angular sides (subtriangular); fibre bundles in the partition layers of the air-cavities (Ht. 40-48 μ; W. 32-52 μ) trapezoid. Secretory cells rare.

Although MULLAN (1945) and D'ALMEIDA & RAMASWAMY (1948) had investigated the leaf anatomy of this species, their account seems to be too fragmentary to be of any value since no specific mention is made about the shape and size of sclerenchyma strands, number of bulliform cells, nature of bundle sheath cells, number and type of vb's, air-cavities, assimilatory tissue, etc. Secretory cells rare and not frequent as reported by them.

CULM. *Epidermis, surface view:* Cells short, broad, variable, thick-walled, smooth. Stomata (L. 36-40 μ; W. 28-32 μ) oblong; subsidiary cells parallel-sided; interstomatal cells short. Silica-cells short, narrow, thin-walled, occurring usually in more or less 2 continuous rows, each cell possessing (1-) 2 conical silica-bodies surrounded by satellites.

Transverse section (Pl. 2, *4*): Outline acutely triangular. Epidermal cells thick-walled. Air-cavities very many, variable, somewhat irregular in distribution, reticulate; air-cavities containing transverse plates of elongated cells with peg-like outgrowths, see lamina (Pl. 4, *6*). Vascular bundles very many, all similar and belonging to type III B; the vb's in the



Pl. 4. — Transverse section of leaf (sheath or lamina), ground plan: **1, Scirpus maritimus** L., lamina × 30; **2**, *id.*, sheath, diagrammatic; **3**, *id.*, sheath, in part × 30; **4, S. juncoides** Roxb., sheath × 24; **5**, *id.*, silica cells in sheath, surface view × 360; **6, S. grossus** L.f., diaphragm cells × 240; **7, S. litoralis** Schrad., T.S. sheath, diagrammatic; **8**, *id.*, sheath, in part × 18; **9, S. jacobi** Fischer, sheath, in part × 150; **10, S. mucronatus** L., sheath, in part × 15; **11**, *id.*, in full, diagrammatic; **12, S. fluitans** L., sheath × 60; **13**, *id.*, lamina × 70; **14, S. lateriflorus** Gmel., sheath × 24; **15, S. subcapitatus** Thw., silica cell in sheath, surface view × 360.

periphery forming a circle; vb's containing protoxylem lacunæ; metaxylem vessel members (D. 32-48 μ in diameter); metaphloem of " regular type". Bundle sheaths: single, parenchymatous, complete. Circumvascular sclerenchyma present as a cap both at xylem and phloem poles in all the vb's. Sclerenchyma: many, hypodermal (Ht. 40-80 μ; W. 48-60 μ), pulviniform strands. Fibre bundles (Ht. & W. 40-60 μ) pentangular, present in the partition of air-cavities. Secretory cells abundant.

MULLAN's description (1945) differs from that of mine in regard to the occurrence of sclerenchyma strands not opposite to vb's and the presence of network of air-cavities in the centre.

For rhizome and root transverse sections, see METCALFE (1971).

MATERIAL EXAMINED: Killai, South Arcot Dt., *Krishnamurthy 360.*

Scirpus jacobi Fischer[1]

SHEATH. *Abaxial surface:* Intercostal cells axially elongated, broad. moderately thick-walled, pitted, smooth; cells containing spindle-shaped (rod-shaped) greenish silica-body per cell. Stomata (L. 44-48 μ; W. 24 μ), narrowly oblong; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells short, broad, thin-walled, smooth, occurring usually in 2 continuous rows, each cell possessing 2 (-3) cone-shaped silica-bodies surrounded by satellites.

Transverse section (Pl. 4, *9*): Cuticle thick on the abaxial surface. Epidermal cells isodiametric, similar on both surfaces. Hypodermis: 2-3-layered parenchyma beneath abaxial epidermis. Air-cavities as many as and alternating with vb's; air-cavities containing lobed parenchyma cells traversed by veins; air-cavities variable, transversely elongated. Sclerenchyma (abaxial: Ht. 24-32 μ; W. 32-40 μ) pulviniform (rounded) strands; adaxial girders (Ht. 40 μ; W. 48 μ) pulviniform. Circumvascular sclerenchyma not developed. Vascular bundles many, rounded, belonging to type III B; metaxylem vessel members (D. 12-16 μ). Bundle sheaths: O.S. of inflated parenchyma cells, I.S. fibrous. Secretory cells large, conspicuous.

CULM. *Epidermis, surface view:* Cells axially elongated, moderately broad, thick-walled, smooth, pitted. Stomata (L. 44-48 μ; W. 24 μ), narrowly oblong, thick-walled; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells short, broad, smooth, thin-walled, present in 2-3 continuous rows, each one of them containing 2 conical silica-bodies with satellites.

Transverse section (Pl. 1, *5*): Outline ovate with wavy margin. Epidermal cells thick-walled. Assimilatory tissue hypodermal, 3-4 layers of palisade chlorenchyma. Air-cavities variable in size and shape approaching

1. This epithet is no longer the earliest available in *Scirpus*, and [should be replaced (combination under *Scirpus* still to be coined, see this vol., p. 149. — Note from the Editor).

the centre and containing stellate parenchyma; air-cavities *c.* 19 in number forming more or less peripheral ring. Vascular bundles *c.* 25, large, medium (type III A) and small (type I); large and medium vb's containing protoxylem lacunæ; medium and small vb's forming more or less a peripheral ring while the large vb's scattered in the centre; metaxylem vessel members (D. 16-20 μ). Bundle sheaths: O.S. parenchymatous, I.S. fibrous, both complete. Circumvascular sclerenchyma deeply crescentiform present as a cap at the xylem pole of all vb's. Sclerenchyma: subepidermal (Ht. 24-32 μ; W. 32-40 μ), pulviniform strands. Secretory cells very abundant in the hypodermis.

ROOT. *Transverse section:* Diameter of the root examined *c.* 0.3 mm. For other details, see *S. fluitans*.

MATERIAL EXAMINED: Thiruvottiyur, Madras Dt., *Govindarajalu 11818;* Vedanthangal, Chinglepet Dt., *Go. 5736;* Aminjikarai, Madras Dt., *Go. 5648;* Gingee, N. Arcot Dt., *Go. 5437;* Sommod river bed, Coimbatore Dt., *Ramakrishnan 6877.*

Scirpus juncoides Roxb.

SHEATH. *Abaxial surface:* Intercostal cells axially elongated, broad, moderately thick-walled, sinuous. Stomate (L. 40-44 μ; W. 20-24 μ), narrowly oblong; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells short, broad, thin-walled, sinuous, occurring in 1-2 continuous rows; silica-bodies conical, 1-2 large per cell and associated with many minute silica-bodies near the end walls; satellites absent (Pl. 4, *5*).

Transverse section (Pl. 4, *4*): Outline circular. Cuticle over the abaxial epidermis thicker than that of the adaxial. Epidermis: cells of the abaxial layer thick-walled while those of the adaxial layer consisting of thin-walled cells. Ground tissue composed of 3-4 layers of chlorenchyma. Air-cavities *c.* 23 disposed in a single row filled with stellate parenchyma cells; air-cavities as many as and regularly alternating with vb's and present near the adaxial epidermis. Sclerenchyma: hypodermal (Ht. 20-32 μ; W. 24-40 μ), trapezoid strands. Vascular bundles *c.* 23, all belonging to (type III A), arranged in a ring; metaxylem vessel members (D. 16-20 μ); metaphloem of " regular type ". Bundle sheaths, see *S. fluitans*. Circumvascular sclerenchyma crescentiform forming a cap at the xylem pole. Secretory cells common.

CULM. *Epidermis, surface view:* Cells elongated, broad, thin-walled, somewhat sinuous. Stomata (L. 40-48 μ; W. 24 μ), elliptical; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells see sheath.

Transverse section (Pl. I, *1*): Outline circular. Cuticle thin. Epidermal cells thin-walled. Assimilatory tissue: 3-4 layers of palisade cells present as a narrow zone at the circumference of the culm. Air-cavities *c.* 12 filled with stellate parenchyma cells; air-cavities variable, reaching the centre and arranged more or less in two circles. Vascular bundles

c. 23, small (type I) and large (type III B); both arranged to form a peripheral circle, additional pair of large vb's facing each other present in the centre; metaxylem vessel members (D. 24-28 μ); large vb's containing protoxylem lacunæ; metaphloem of " regular type ". Bundle sheaths, see sheath. Circumvascular sclerenchyma, see sheath. Sclerenchyma (Ht. 24-32 μ; W. 36-40 μ), hypodermal trapezoid (pulviniform) strands. Secretory cells very common in the midst of assimilatory tissue.

ROOT. *Transverse section:* Diameter of the root examined *c.* 0.6 mm. Epidermis, outer cortex, see *S. fluitans;* inner cortex consisting of a single layer of parenchyma cells arranged in radial alignment with endodermal cells. Hypodermis composed of 2-3 layers of parenchyma cells. Endodermis: cells isodiametric, thin-walled. Metaxylem element, see *S. fluitans;* metaxylem vessel member (D. 48-52 μ); metaphloem not easily recognizable; protoxylem units 10 in number. Central ground tissue parenchymatous.

MATERIAL EXAMINED: Thandikudi, Kodaikanal, Madurai Dt., *Bourne 1434;* Bangalore, Mysore state, *Thangavelu 14;* Hebbal, Bangalore Dt., *Vasudeva Rao 7861;* Cumbum, Madurai Dt., *Baskaran 18.*

Scirpus lateriflorus Gmel.

SHEATH. *Abaxial surface:* Intercostal cells axially elongated, narrow, thick-walled, smooth. Stomata (L. 44-48 μ; W. 24-28 μ), narrowly oblong, thick-walled; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells elongated, narrow, thin-walled, smooth, occurring in 1-2 discontinuous rows; each cell characterized by possessing (3-) 4-5 small cone-shaped silica-bodies surrounded by satellites.

Transverse section (Pl. 4, *14*): Outline thickly V-shaped with median adaxial groove. Cuticle moderately thick. Epidermal cells isodiametric, thick-walled. Assimilatory tissue hypodermal, consisting of several-layered palisade chlorenchyma. Air-cavities *c.* 13, variable, radially elongated, more or less arranged in a regular pattern and regularly alternating with vb's, each one of them filled with stellate parenchyma cells; partition of air-cavities containing chlorenchyma cells. Adaxial hypodermis consisting of a single layer of parenchyma cells. Vascular bundles *c.* 16, represented by large (type III A) and small (type I) vb's arranged in a single circle nearer to abaxial surface; major vb's containing protoxylem lacunæ; metaxylem vessel members (D. 24-28 μ); metaphloem of " regular type "; outlines of vb's oval to circular. Bundle sheaths: O.S. parenchymatous composed of enlarged cells; I.S. fibrous, both complete. Circumvascular sclerenchyma 1-2-layered, crescentiform. Sclerenchyma strands (Ht. 32-40 μ; W. 40-48 μ abaxial), subepidermal, trapezoid (rounded); adaxial strands (Ht. 32 μ; W. 44-64 μ), *c.* 3 in number, trapezoid. Secretory cells abundant in the hypodermis.

CULM. *Epidermis, surface view:* Cells elongated, narrow, moderately thick-walled, pitted, sinuous. Stomata (L. 40-44 μ; W. 24-32 μ),

elliptical, moderately thick-walled; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells elongated, narrow, thin-walled, smooth, occurring in 2 discontinuous rows, each cell possessing 2-3 (-4) rather large conical silica-bodies with satellites.

Transverse section (Pl. 1, *3*): Outline obtusely triangular. Cuticle thick. Epidermal cells moderately thick-walled, isodiametric. Assimilatory tissue hypodermal, consisting of many-layered palisade chlorenchyma. Air-cavities *c.* 13, variable, forming a perimedullary circle; air-cavities containing transverse plates of elongated chlorenchyma cells with peg-like lobes and not regularly alternating with vb's. Vascular bundles *c.* 20, comprising large (type III B) and small vb's (type I); peripheral circle composed of large and small vb's, 16 in number followed by an inner circle of 4 large vb's; vb's oval to rounded in outline; large vb's with protoxylem lacunæ; metaxylem vessel members (D. 20-32 μ); metaphloem belonging to "regular type". Bundle sheaths: O.S. organized by large, radiating cells of parenchyma; I.S. fibrous, both complete. Circumvascular sclerenchyma present as a crescentiform cap at the xylem poles and in certain vb's at the phloem poles also. Central ground tissue parenchymatous. Sclerenchyma strands (Ht. 40-68 μ; W. 60-80 μ), subepidermal, pulviniform (triangular). Secretory cells abundant in the midst of assimilatory tissue.

ROOT. *Transverse section:* Diameter of the root examined 0.5 mm. Endodermis prominent, cells with U-shaped thickenings and broad lumina. Metaxylem elements 2, central; protoxylem units 10 in number; metaxylem vessel members (D. 24-36 μ). Other details as in *S. juncoides*.

MATERIAL EXAMINED: Courtallam, Tirunelveli Dt., *Rajasekaran & Thanyakumar 10313;* Thiruvottiyur, Madras Dt., *Govindarajalu 11830;* Tirupati, Chittoor Dt., *Ra. & Rangarajan 11291;* Poondi, Madras Dt., *Go. 8986;* Sammod river side, Coimbatore Dt., *Ramakrishnan 6876;* Ennore, Madras Dt., *Go. 5617, 5618;* Red Hills, Madras state, *Go. 5557;* Gingee, N. Arcot Dt., *Go. 5433;* Nagercoil, Kanyakumari Dt., *Go. 6984;* Manganallur, Thanjavur Dt., *Go. 5803;* Kumbakonam, Thanjavur Dt., *Duraiswamy 7144.*

Scirpus litoralis Schrad.

SHEATH. *Abaxial surface:* Intercostal cells axially elongated, broad, thin-walled, smooth. Stomata (L. 40-44 μ; W. 28-32 μ), narrowly oblong, thick-walled; subsidiary and interstomatal cells, see *S. jacobi*. Silica-cells elongated, narrow, thin-walled, smooth, occurring in a single discontinuous row, each cell containing 4-5 (-6) cone-shaped small silica-bodies; satellites absent.

Transverse section (Pl. 4, *7, 8*): Outline thinly crescentiform. Epidermal cells similar on both surfaces. Stomata possessing both outer and inner ledges; substomatal chamber very narrow. Hypodermis: both abaxial and adaxial layers consisting of parenchyma cells. Air-cavities containing lobed parenchyma cells traversed by veins, arranged in a single

row and regularly alternating with vb's. Sclerenchyma strands variable (abaxial: Ht. 20-40 μ; W. 24-44 μ) trapezoid, pulviniform, rounded with angular sides; adaxial strands (Ht. 24-40 μ; W. 24-32 μ) polyhedral and irregularly shaped. Vascular bundles many, large (type III A) and small (type I), both showing almost regular alternation; larger vb's characterized by protoxylem lacunæ; metaxylem vessel members (D. 12 μ); metaphloem of " regular type ". Bundle sheaths: O.S. of inflated parenchyma cells; I.S. fibrous. Circumvascular sclerenchyma present as a rectangular cap at the xylem pole. Secretory cells rare.

CULM. *Epidermis, surface view :* Cells variable, broad, moderately thick-walled, smooth. Stomata (L. 40-44 μ; W. 32 μ), more or less circular, not common; subsidiary cells parallel-sided; interstomatal cells moderately elongated. Silica-cells elongated, narrow, thin-walled, smooth, present in a single discontinuous row; silica-bodies (3-) 4 (-5), conical, not surrounded by satellites, sometimes occurring in united condition (compound).

Transverse section (Pl. 2, *6*): Diameter of the culm examined *c.* 5.0 mm. Outline ovate with ridges but circular in living materials. Epidermal cells isodiametric, thin-walled. Assimilatory tissue 2-3 layers of short palisade cells. Air-cavities very many, rather variable, forming a continuous reticulum, containing plates of transversely elongated cells with peg-like lobes, see lamina of *S. grossus* (Pl. 4, *6*) and traversed by transverse vascular connections. Vascular bundles many, comprising large (type III B), medium (type III A) and small bundles (type I), the latter two kinds of vb's forming a peripheral circle; large vb's having protoxylem lacunæ and scattered in the centre; metaxylem vessel members (D. 36-40 μ); metaphloem of " regular type ". Bundle sheaths: O.S. parenchymatous, I.S. fibrous, both complete; O.S. of large vb's composed of inflated radiating cells. Circumvascular sclerenchyma of large and medium vb's forming a crescentiform cap at the xylem pole; of small vb's forming a triangular cap at the xylem pole (Pl. 2, *7*). Sclerenchyma strands (Ht. 16-32 μ; W. 36-40 μ), hypodermal, pulviniform; fibre bundles variable in shape abundant in the midst of the assimilatory tissue, each composed of 4-6 cells. Secretory cells less common.

STOLON. *Epidermis, surface view:* Cells axially elongated, thin-walled, smooth, more or less hexagonal. Stomata few, usually paracytic. sometimes tetracytic (L. 22.5-27.0 μ; W. 45-49.5 μ); subsidiary cells low dome-shaped sometimes parallel-sided and extending beyond the poles of the stomata; interstomatal cells elongated with more or less straight end walls; guard cells containing many silica-bodies variable in size and shape but usually oval or bluntly cone-shaped or triangular.

Transverse section : Diameter of the stolon examined *c.* 1.15 mm. Outline circular to ovate. Cuticle thin. Epidermal cells isodiametric. Assimilatory tissue: 2-3 layers of palisade cells. Stomata with outer and inner ledges; substomatal chamber very narrow. Sclerenchyma: hypo-

dermal (Ht. 22.5-27.0 μ; W. 45-49.5 μ), pulviniform strands; strands at the inner limits of assimilatory tissue (Ht. & W. 27.0 μ), rounded. Air-cavities *c.* 6, lysigenously formed, variable in shape and size; partition walls 2-3-layered containing pentangular fibre bundles. Vascular bundles *c.* 15-18, arranged in a peripheral circle; vb's large (type III A) and small (type I) not regularly alternating with each other; vb's circular in outline with more or less angular sides. Bundle sheaths: single-layered, parenchymatous, complete. Metaphloem belonging to " regular type ". Secretory cells absent.

ROOT. *Transverse section:* Diameter of the root examined *c.* 0.6 mm. Root hairs present. Exodermal cells variable, thin-walled. Hypodermis: 2 layers of parenchyma. Cortex consisting of several air-cavities concentrically arranged and being separated by radiating rows of parenchyma and internally delimited by 2 layers of more or less compactly arranged parenchyma cells. Endodermis: 1-layered composed of broad-lumened isodiametric cells with thickening restricted to the outer tangential walls only. Pericycle distinct, parenchymatous, the continuity of which broken by protoxylem elements. Metaxylem vessel members (D. 36.0 μ), large, central, solitary, circular in outline; protoxylem units 6 in number alternating with as many metaphloem units; metaphloem consisting of 5-6 cells out of which 2-3 being large sieve tube elements, the rest companion cells. Ground tissue within the stele parenchymatous.

D'ALMEIDA & RAMASWAMY (1948) noted a central cavity instead of central metaxylem vessel element.

MATERIAL EXAMINED: Tiruvottiyur, Madras Dt., *Govindarajalu 5760, 12722.*

Scirpus maritimus L.

LEAF. *Abaxial surface:* Intercostal cells moderately elongated, variable, broad, thick-walled, smooth, pitted; end walls straight. Stomata (L. 40-44 μ; W. 28-32 μ), oval, thick-walled; subsidiary cells low dome-shaped; interstomatal cells short with concave ends. Silica-cells short, narrow, thin-walled, smooth, occurring in two more or less continuous rows, each cell containing 2 small conical silica-bodies not surrounded by satellites.

Adaxial surface: Cells shortly hexagonal, variable, thin-walled, smooth; end walls straight. Stomata abundant (L. 32-40 μ; W. 24 μ), elliptic, thin-walled; subsidiary and interstomatal cells, see abaxial surface. Silica-cells short, thin-walled, smooth, occurring in 2 continuous rows, each cell possessing 2-3 conical silica-bodies with satellites.

Lamina, transverse section (Pl. 4, *1*): Outline flat with abaxial keel and corrugated surfaces but said to be widely V-shaped by METCALFE (1971). Cuticle very thick on both surfaces. Adaxial epidermal cells larger than those of the abaxial. Keel obtusely triangular. Margins obtuse. Assimilatory tissue occurring in more or less palisade layers

throughout the mesophyll. Air-cavities *c.* 16, variable, alternating with vb's; air-cavities containing stellate parenchyma cells (cf. METCALFE, 1971). Bulliform cells occurring in 4 layers, the outer consisting of 7, followed by the inner one of 16-17 cells both forming a regular fan-shaped group; the two innermost layers consisting of 2 more or less radially elongated cells in each. Vascular bundles 14 with 1 median vb in the keel (cf. METCALFE, 1971); vb's comprising large (type III B) and small (type III A), more or less alternating with each other; metaxylem vessel members (D. 20 μ); metaphloem of " regular type ". Bundle sheaths: single, fibrous, complete. Circumvascular sclerenchyma crescentiform in the large vb's and rectangular in the small vb's and in both forming caps at the xylem poles. Sclerenchyma strands (Ht. 16-32 μ; W. 24-40 μ) pulviniform, subepidermal to abaxial and adaxial epidermis and on either sides of the keel vb; girders not seen (cf. METCALFE, 1971). Secretory cells abundant throughout.

SHEATH. *Abaxial surface:* Intercostal cells moderately elongated, broad, thin-walled, moderately sinuous. Stomata not observed. Silica-cells elongated, narrow, thin-walled, smooth, present in 2 continuous rows; silica-bodies 4, conical in each cell, not surrounded by satellites.

Transverse section (Pl. 4, *2*, *3*): Outline thinly crescentiform. Cuticle thicker on the adaxial surface. Abaxial and adaxial epidermal cells thick-walled. Air-cavities very many, containing stellate parenchyma cells and regularly alternating with vb's. Sclerenchyma strands (Ht. & W. 20-40 μ), rounded, occupying the subepidermal position of the adaxial surface. Circumvascular sclerenchyma 3-4-layered, crescentiform, forming a cap at the xylem pole. Vascular bundles many, varying in size (type III A), arranged in the partitions of the air-cavities forming a single row; vessel members (D. 16-24 μ); metaphloem of " regular type ". Secretory cells not common.

CULM. *Epidermis, surface view:* Cells short, variable, rather broad, thick-walled, somewhat sinuous. Stomata (L. 32-40 μ; W. 24-28 μ), narrowly oblong, thick-walled; subsidiary cells parallel-sided; interstomatal cells short. Silica-cells short, narrow, thin-walled, smooth, occurring in 1-2 discontinuous rows, each one of them possessing 2 large cone-shaped silica-bodies without satellites.

Transverse section (Pl. 3, *3*): Outline acutely triangular. Epidermal cells thick-walled. Substomatal chamber narrow and small. Assimilatory tissue: 3-4 layers of chlorenchyma. Air-cavities absent (cf. METCALFE, 1971). Vascular bundles *c.* 34, large (type III A) and small (type I), the former containing protoxylem lacunæ; both types of vb's arranged to form a peripheral circle without showing regular alternation; few large vb's in the centre scattered (cf. METCALFE, 1971); metaxylem vessel members (D. 20-24 μ); metaphloem of " regular type ". Bundle sheaths: single-layered, fibrous, complete but not easily recognizable. Circumvascular sclerenchyma 2-3-layered, forming a complete sheath in all the vb's thus

obscuring the bundle sheaths. Sclerenchyma girders (Ht. 40-60 μ; W. 40-64 μ), securiform; strands (Ht. 20-40 μ; W. 32-52 μ) pulviniform or rectangular. Central ground tissue parenchymatous. Secretory cells abundant in the midst of assimilatory tissue.

STOLON. *Transverse section:* Diameter of the stolon examined *c.* 0.6 mm. Epidermal cells thick-walled, suberized, variable. Cortex lacunose due to the presence of air-cavities varying in size and shape. Endodermis : prominent composed of cells with uniform thickening throughout and narrow lumina. Pericycle distinct, sclerenchymatous; cells radially elongated, hexagonal. Vascular bundles many; perimedullary vb's disposed in a circle while the central ones scattered; vb's belonging to type III B and sometimes found united laterally with the adjacent vb's; metaxylem vessel members (D. 36-40 μ); metaphloem of " regular type ". Circumvascular sclerenchyma forming a complete sheath. Central ground tissue parenchymatous.

ROOT. *Transverse section:* Diameter of the root examined *c.* 0.5 mm. Exodermis: cells thick-walled, suberized, variable. Endodermis: cells isodiametric with uniform thickening throughout and circular broad lumina. Metaxylem vessel members (D. 56 μ), solitary, central. Pericycle not easily recognizable. Other details as in *S. fluitans.*

FREIDENFELT's (1904) description differs as follows: endodermal cells radially elongated with U-shaped thickenings, pericycle of thin-walled cells and 2 large central vessels in the stele.

MATERIAL EXAMINED: Somnad river side, Coimbatore Dt., *Ramakrishnan 6879.*

Scirpus mucronatus L.

SHEATH. *Abaxial surface:* Intercostal cells axially elongated, narrow, thin-walled, smooth. Stomata not observed. Silica-cells elongated narrow, thin-walled, smooth, occurring in 2 continuous rows; silica-bodies 3-4 conical, surrounded by satellites in each cell.

Transverse section (Pl. 4, *10*, *11*): Outline broadly V-shaped. Abaxial epidermal cells larger than those of the adaxial. Cuticle thick. Air-cavities *c.* 18 rather variable, and regularly alternating with vb's; air-cavities filled with stellate parenchyma cells and arranged in a circle. Sclerenchyma strands (Ht. 40-56 μ; W. 48-60 μ), trapezoid (pulviniform) situated next to adaxial epidermis. Vascular bundles *c.* 19, of one size, all belonging to type III A, arranged in a single horizontal row; metaxylem vessel members (D. 16-24 μ); metaphloem of " regular type ". Bundle sheaths: O.S. parenchymatous; I.S. sclerenchymatous, both complete. Circumvascular sclerenchyma 2-layered, forming a crescentiform cap at the xylem poles. Secretory cells not common.

CULM. *Epidermis, surface view:* Cells axially elongated, narrow, thick-walled, pitted, smooth. Stomata (L. 52-56 μ; W. 20-24 μ), narrowly

oblong, thick-walled; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells elongated, narrow, thin-walled, smooth, developed in 2 continuous rows; silica-bodies (4-) 8 (-12), conical and surrounded by satellites in each cell.

Transverse section (Pl. 2, *1*): Outline acutely triangular. Epidermal cells thick-walled. Cuticle very thick, smooth. Assimilatory tissue: 3-4 layers of hypodermal palisade chlorenchyma. Air-cavities variable. many, arranged in an orderly pattern after the transectional outline of the culm, many of them radially elongated and reaching the centre; those at the corners are much smaller; air-cavities containing stellate parenchyme and *c.* 35 in number. Vascular bundles *c.* 54 comprising both larga (type III B) and small (type III A); peripheral circle consisting of *c.* 45 small vb's aligned at the inner boundary of chlorenchyma; *c.* 9 large vb's arranged in a triradiate manner in the centre; the peripheral vb's alternating almost with air-cavities except a few; large vb's containing protoxylem lacunæ; each corner of the culm containing a pair of vb's out of which the inner vb's larger than the outer; metaxylem vessel members (D. 40-44 μ). Bundle sheaths, circumvascular sclerenchyma, see *S. maritimus*. Sclerenchyma strands many (Ht. & W. 20-40 μ), rounded to pulviniform (triangular). Secretory cells abundant in the hypodermis.

RHIZOME. *Transverse section:* Diameter of the rhizome examined *c.* 3.7 mm. Cuticle thick. Epidermal cells thick-walled. Sclerenchyma strands (Ht. 120-140 μ; W. 100-120 μ), pulviniform to rounded. Cortex parenchymatous. Endodermis prominent consisting of a single layer of uniformly thickened, isodiametric cells having broad lumina. Vascular bundles (type V), many; perimedullary vb's forming a ring while the remainder scattered; metaphloem of "regular type". Bundle sheaths: single, parenchymatous, complete. Circumvascular sclerenchyma 1-2-layered, sometimes forming a cap. Central ground tissue of compactly arranged parenchyma. Secretory cells and starch grains abundant in the cortex and central ground tissue.

ROOT. *Transverse section:* Diameter of the root examined *c.* 0.7 mm. Exodermis: single-layer of thin-walled cells. Hypodermis: single-layered, sclerenchymatous. Cortex: outer broad, containing several air-cavities arranged in a concentric manner and separated from each other by radiating rows of parenchyma cells; inner cortex of 4 layers of compactly arranged parenchyma cells disposed in radial alignment with the endodermal cells. Endodermis prominent composed of isodiametric cells with U-shaped thickening and broad lumina. Pericycle distinct, sclerenchymatous. Metaxylem elements, see *S. fluitans;* metaxylem vessel members (D. 28-32 μ); protoxylem units 9 in number and alternating with as many metaphloem units, each unit in the latter containing a single large sieve tube element and 3 companion cells. Central ground tissue sclerenchymatous.

MATERIAL EXAMINED: Nilgiris, Nilgiris Dt., *Govindarajalu 6237, 9109;* Muthukuzhi, Kanyakumari Dt., *Ernest Thayasingh 8573;* Nellikkampatti, Thekkady, Kerala state,

Go. 6533; Yercaud, Salem Dt., *Fyson 7046;* Siruvani, Coimbatore Dt., *Rajasekaran 7023;* Munnar, Madurai Dt., *Jagannathan 26;* Kodhaiyar, Kanyakumari Dt., *Go. 7637;* Kodaikanal, Madurai Dt., *Fyson 4370;* Valparai, Coimbatore Dt., *Go. 10858.*

Scirpus roylei (Nees) Parker

SHEATH. *Abaxial surface:* Intercostal cells elongated, narrow, thick-walled, pitted, smooth. Stomata (L. 52-56 μ; W. 24-28 μ), narrowly oblong, thick-walled; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells elongated, thin-walled, smooth, narrow, developed in 1-2 continuous rows, each cell containing 8-10 small conical silica-bodies with satellites.

Transverse section: Cuticle very thick on both surfaces. Abaxial and adaxial epidermal cells thick-walled. Adaxial epidermal cells larger than those of the abaxial. Hypodermis: single layer of parenchyma in the abaxial surface. Air-cavities as many as and alternating with vb's; air-cavities containing stellate parenchyma. Sclerenchyma strands (Ht. 20-32 μ; W. 24-40 μ), rounded to pulviniform. Circumvascular sclerenchyma of 1-2 layers forming a rectangular cap at the xylem poles. Vascular bundles many, distributed in a single row and all belonging to type I; metaxylem vessel members (D. 8 μ); metaphloem not easily recognizable. Bundle sheaths: single, fibrous, complete. Secretory cells common.

CULM. *Epidermis, surface view:* Cells elongated, narrow, thin-walled, smooth. Stomata (L. 44-48 μ; W. 20-24 μ), narrowly oblong, thick-walled; subsidiary cells parallel-sided; interstomatal cells elongated. Silica-cells elongated, narrow, thin-walled, smooth, disposed in 1-2 almost continuous rows; silica-bodies conical, 5-6 having satellites present in each cell.

Transverse section (Pl. 1, *4*): Outline obtusely triangular with ridges. Cuticle thick, smooth. Epidermal cells thick-walled. Assimilatory tissue of *c.* 2-4 layers of palisade chlorenchyma in the hypodermis. Air-cavities *c.* 16, variable, arranged to form more or less a peripheral circle, not approaching the centre filled with stellate parenchyma cells; cells in the partition layers of the air-cavities with some gelatinous content? Vascular bundles *c.* 20 of two sizes, large (type III B) and small (type I) and arranged in more or less two circles, outer circle consisting of *c.* 15 vb's, the inner of *c.* 5 vb's but in outer circle both large and small vb's present; large vb's with protoxylem lacunæ; metaxylem vessel members (D. 28 μ); metaphloem belonging to " regular type ". Bundle sheaths and circumvascular sclerenchyma, see *S. mucronatus*. Sclerenchyma strands (Ht. 28-40 μ; W. 32-40 μ), variable (pulviniform, rounded, subtriangular). Secretory cells occasional.

SABNIS (1921) noted circular outline for the culm and secretory cells in the chlorenchyma.

ROOT. *Transverse section:* Diameter of the root examined *c.* 0.5 mm. Inner cortex of 2-3 layers of parenchyma cells arranged in radial alignment

with the endodermal cells. Metaxylem vessel members (D. 72 μ); protoxylem units 8 in number and alternating with as many metaphloem units, each unit in the latter comprising a single large sieve tube element and 3 companion cells. For other details, see *S. fluitans.*

MATERIAL EXAMINED: Bhubaneshwar, Orissa state, *Thangavelu 7053.*

Scirpus subcapitatus Thw.

SHEATH. *Abaxial surface:* Intercostal cells short, narrow, variable, exceedingly thick-walled, pitted, sinuous. Stomata (L. 44-48 μ; W. 28-32 μ), elliptical, thick-walled; subsidiary cells parallel-sided; interstomatal cells short with straight end walls. Silica-cells short, broad, thin-walled, sinuous, occurring in 3 discontinuous rows; each one of them including 2-5 (-6) small conical silica-bodies without satellites arranged in two rows (Pl. 4, *15*).

Transverse section: Cuticle exceedingly thick, lamellated, that of the abaxial surface thicker than that of the adaxial. Abaxial and adaxial epidermal cells thick-walled. Hypodermis (abaxial) consisting of 2 layers of sclerenchyma; adaxial hypodermis of 2-3 layers of parenchyma. Air-cavities *c.* 25 containing stellate parenchyma cells and regularly alternating with as many vb's. Sclerenchyma girders (Ht. 40-60 μ; W. 80-120 μ), crescentiform. Vascular bundles *c.* 25, comprising large (type III B) and small (type I) arranged nearer to abaxial surface in a single row and almost regularly alternating with each other; metaxylem vessel members (D. 12-16 μ); metaphloem of " intermediate type ". Bundle sheaths: O.S. parenchymatous, incomplete; I.S. fibrous, complete. Circumvascular sclerenchyma present as a crescentiform cap at the xylem poles. Secretory cells abundant.

CULM. *Epidermis, surface view:* Cells short, narrow, variable, exceedingly thick-walled, pitted, somewhat sinuous. Stomata (L. 44-48 μ; W. 28-32 μ), elliptical, exceedingly thick-walled; subsidiary cells parallel-sided; interstomatal cells short. Silica-cells short, rather broad, thin-walled, occurring in 3 discontinuous rows; silica-bodies 1-2 (-3) conical, small with satellites in each cell.

Transverse section (Pl. 3, *5*): Outline circular. Cuticle very thick, warty. Epidermal cells isodiametric, thick-walled. Assimilatory tissue of compactly arranged, several-layered chlorenchyma, hypodermal. Air-cavities absent. Vascular bundles *c.* 29 comprising large, medium (type III A) and small vb's (type I), all arranged in the periphery to form a circle; vb's of different types not showing regular alternation with each other; metaxylem vessel members (D. 20 μ); metaphloem of " regular type "; large vb's without protoxylem lacunæ; outline of vb's oval to elliptical in outline. Bundle sheaths: single-layered, fibrous, complete. Circumvascular sclerenchyma crescentiform in small and medium vb's, forming

caps both at xylem and phloem poles and in the case of large vb's at the xylem pole only. Sclerenchyma girders (Ht. 100-120 μ; W. 80-120 μ), T-shaped, present in association with the large vb's. Central ground tissue consisting of abruptly enlarged compactly arranged parenchyma. Secretory cells abundant in the hypodermis.

ROOT. *Transverse section* (Pl. 3, *4*): Diameter of the root examined *c.* 0.9 mm. Outline circular. Epidermis: palisade layer of moderately thick-walled, radially elongated cells. Exodermis: a single layer of thick-walled, isodiametric cells; cells containing cone-shaped silica-bodies projecting from the walls. Cortex: outer narrow composed of 3-4 layers of sclerenchyma; middle cortex lacunose, characterized by *c.* 13 air-cavities separated by radiating rows of parenchyma; inner cortex narrow, consisting of 5-6 layers of sclerenchyma. Endodermis: prominent, cells isodiametric with U-shaped thickenings and broad lumina. Pericycle not distinct. Metaxylem elements *c.* 15 in number forming a perimedullary ring with as many protoxylem units; metaphloem not easily recognizable. Central ground tissue sclerenchymatous.

MATERIAL EXAMINED: Kodaikanal, Madurai Dt., *Ramakrishnan 6831, Thanikaimoni 7077.*

Scirpus validus Vahl (only culm available)

CULM. *Epidermis, surface view:* Cells short, somewhat isodiametric, smooth, thick-walled. Stomata abundant (L. 16.2-18.0 μ; W. 10.8-12.6 μ); subsidiary cells parallel-sided; interstomatal cells short; silica-cells elongated, slightly broad, occurring in 2-3 continuous rows; silica-bodies 2-3 in each cell with satellites.

Transverse section (Pl. 2, *2, 3*): Outline elliptic-rounded or suborbicular, see *S. brachyceras*. Epidermal cells, stomata see *S. brachyceras*. Assimilatory tissue consisting of 3-4 layers of palisade chlorenchyma and following this, 3-4 layers of rounded to polygonal parenchyma cells present. Air-cavities very many, variable in size and shape, reticulate, approaching the centre, each one of them containing stellate parenchyma cells. Vascular bundles very many, large (type III B), medium and small vb's (type III A); medium and small vb's regularly alternating with each other, disposed in a peripheral circle; large vb's containing protoxylem lacunæ; metaxylem vessel members (D. 18.0-21.6 μ); metaphloem of " regular type ". Bundle sheaths: single-layered, fibrous, complete. Circumvascular sclerenchyma forming crescentiform caps at xylem and phloem poles in all central large vb's; rectangular or triangular caps at xylem poles in small and medium vb's; circumvascular sclerenchyma of vb's encircled by air-cavities (in the partitions) forming more or less rectangular caps both at xylem and phloem poles. Sclerenchyma strands, subepidermal (Ht. 23.4-27.0 μ; W. 27.0-28.8 μ), pulviniform; small fibre bundles (Ht. 10.8-12.6 7; W. 5.4-12.6 μ) embedded in palisade chlorenchyma, each one of them occurring in units

of (2-) 3-6 cells and alternating with subepidermal strands. Secretory cells not seen but reported to be present by METCALFE (1971).

MATERIAL EXAMINED: Andamans, *Govindarajalu 11725, 11730.*

KEY BASED ON CHARACTERS VISIBLE IN EPIDERMIS & T.S. CULM

Bundle sheaths of vb's single-layered; silica-bodies with satellites.
- Fibre bundles present in the partition of air-cavities.
  - Outline acutely triangular; fibre bundle pentangular; air-cavities containing parenchyma with peg-like lobes..... *S. grossus.*
  - Outline elliptic-rounded or suborbicular; fibre bundles both squarrish and pentangular; air-cavities with stellate parenchyma ..... *S. validus.*
- Fibre bundles absent in the partition of air-cavities.
  - Outline obtusely tetragonous; air-cavities containing both stellate and lobed parenchyma ..... *S. brachyceras.*
  - Outline circular; air-cavities absent..... *S. subcapitatus.*
  - Outline ovate with ridges (circular in living); air-cavities containing parenchyma with peg-like lobes..... *S. litoralis.*

Bundle sheaths of vb's double-layered.
- Fibre bundles present in the partition of air-cavities.
  - Outline acutely triangular; strands pulviniform to rectangular. ..... *S. maritimus.*
  - Outline obtusely triangular with ridges; strands variable..... *S. roylei.*
  - Outline obtusely triangular without ridges; strands pulviniform to triangular ..... *S. lateriflorus.*
- Fibre bundles absent in the partitions of air-cavities.
  - Outline circular.
    - Sclerenchyma strands trapezoid to polyhedral; air-cavities containing lobed parenchyma ..... *S. articulatus.*
    - Sclerenchyma strands triangular (pulviniform); air-cavities containing stellate parenchyma ..... *S. juncoides.*
  - Outline scutiform; silica-bodies 3 per cell ..... *S. fluitans.*
  - Outline ovate with wavy margin; silica-bodies 2 per cell..... *S. jacobi.*
  - Outline acutely triangular; silica-bodies usually 8 per cell... *S. mucronatus.*

CONCLUSION

The anatomical structure of 13 species of *Scirpus s. lato* has been described. Among several noteworthy interspecific differences that have come to light, the transectional outlines of the culms in different species presenting different shapes are so revealing and specific that this particular feature alone seems to provide not only a primary mark of distinction but of major importance. Other collateral key characters such as the nature of the bundle sheaths, presence or absence of fibre bundles, number of silica-bodies per cell, cellular contents of air-cavities and sclerenchyma strands have also been used in varying combination for the anatomical identification of the species.

Key to figure lettering and text abbreviations

AB.E. abaxial epidermis
A.C. air-cavity
AD.E. adaxial epidermis
B.C. bulliform cells
CH. chlorenchyma
CU. cuticle
C.V.S. circumvascular sclerenchyma
D. diaphragm
E. epidermis
EN. endodermis
EX. exodermis
S.P. silica particle
S.S. sclerenchyma strand
ST. stellate parenchyma
T.I. tannin idioblast
V.B. vascular bundle
F.B. fibre bundle
HY. hypodermis
L.P. lobed parenchyma
M.V. metaxylem vessel
P. parenchyma
PH. metaphloem
P.L. protoxylem lacunæ
S. sheath
S.B. silica-body
SC.P. sclerosed parenchyma
S.G. sclerenchyma girder
D. diameter
Ht. height
I.S. inner bundle sheath
L. length
O.S. outer bundle sheath
T.S. transverse section
vb. vascular bundle (plural vb's)
W. width

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